Between all-for-one and each-for-himself: On-farm competition for labour as determinant of wetland cropping in two Beninese villages

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Abstract

In sub-Saharan Africa, unexploited land and water resources in wetlands represent an important potential for intensified, sustainable and food-secure farms through rice production and market gardening. The lack of uptake of cropping in wetlands may be related to the ways in which resources are divided between family fields and individual fields. The management system on sub-Saharan African farms comprises a family management unit or a combination of a family management unit and one or more individual management units. The family management unit or the farm head controls production in family fields to satisfy family needs while the individual management units control production in individual fields to satisfy individual needs. Our objective was to investigate the diversity in farm management systems and the resulting uptake of cropping in wetlands for different farm types, as the first step towards suggestions for enhancing rice production and market gardening in wetlands.

We studied farms in two case-study villages in Benin: Zonmon in the southern part and Pelebina in the north-western part.

Farm typologies were developed based on random samples of 51 out of 134 farms (38%) from Zonmon and 50 out of 146 farms (34%) from Pelebina by combining principal component analysis and Ward's minimum variance clustering. Variables included in the PCA were related to levels of resource endowment (e.g., amounts of land, family labour, cash for purchasing chemical inputs and hiring labour) and to resource-use strategies including resource division between family fields and individual fields, and between uplands and wetlands.

We identified 3 farm types in Zonmon and 5 farm types in Pelebina based on differences in resource-use strategies and in resource endowment. We found no trade-off between the existence of individual fields and the area under rice and market garden crops in wetlands. Labour abundance was the main factor driving both the occurrence of individual fields and the expansion of cropping in wetlands. Differences in labour division strategies between family and individual fields among farm types reflected differences in food and cash division strategies. Land use appeared strongly motivated by food self-sufficiency objectives and labour productivity, leading to prioritisation of upland over wetland areas. In wetlands, most farm types opted for cultivating market garden crops during the dry season when labour demand for upland fields was low. Our results indicate that increasing labour productivity in food crops and in rice and market garden crops would enhance the uptake of rice and market garden crops in wetlands. Creating credit facilities would increase the labour resource and allow farmers to hire labour, further contributing to wetland use. We discuss the relevance of a systemic farm analysis that enables distinguishing family and individual fields for understanding farm uptake of rice and market garden crops in wetlands.

Keywords

Farm typology; Management system; Production system; Wetlands; Labour

1. Introduction

The Sustainable Development Goals, in particular goal 2, set the ambitious target of achieving global food security by 2030 (UN, 2015). In 2015, 23% of the sub-Saharan African population was estimated to be undernourished (FAO et al., 2015). Long-term food security is impaired by unsustainable land use (Bossio et al., 2010; McIntyre et al., 2009; Mirzabaev et al., 2015): in Africa, 65% of agricultural land was estimated to be affected by some form of degradation for the year 1990 (Oldeman, 1991). At the same time, unexploited land and water resources in wetlands represent an important potential for intensified and sustainable land use (Balasubramanian et al., 2007; Giertz et al., 2012; Rodenburg et al., 2014; Saito et al., 2013; Wakatsuki and Masunaga, 2005; Windmeijer and Andriesse, 1993). Following the 2008 food crisis, governments of 19 African countries developed national strategies to exploit wetland resources and ensure rice self-sufficiency (Demont, 2013; Demont and Ndour, 2014). In Benin, the government decided to enhance both the rice and the market garden crop sectors (MAEP, 2011a, 2011b), as both may contribute to farm sustainable intensification and food security (Erenstein et al., 2006; Lu et al., 2010; Singbo and Lansink, 2010).

Farm systems are described as comprising a production system and a management system, the latter controlling production (Dogliotti, 2011; McCown, 2001; Sorensen and Kristensen, 1992). In sub-Saharan African wetland agricultural systems, the production system on farms can include upland fields, wetland fields or a combination of upland and wetland fields (Rebelo et al., 2010; Sakané et al., 2013). In sub-Saharan Africa, most farms are family farms. The management system on these farms comprises a family management unit or a combination of a family management unit and one or more individual management units. The literature provides evidence that 2 types of fields can coexist within family farms: family fields (also denoted as collective fields, common fields, jointly-managed fields or mixed-managed fields) and individual fields (Guirkinger et al., 2015; Kazianga and Wahhaj, 2013). Family fields are supervised by the farm head to satisfy family needs. In family fields, the whole family works as a team and the farm head decides on crops, management sequences (Sebillotte, 1974) and profit distribution among the farm family members. Individual fields are granted by the farm head to a family worker for individual use and profit. As a result, farm systems may reveal a complex combination of family fields in uplands, individual fields in uplands, family fields in wetlands and individual fields in wetlands (Figure 1).

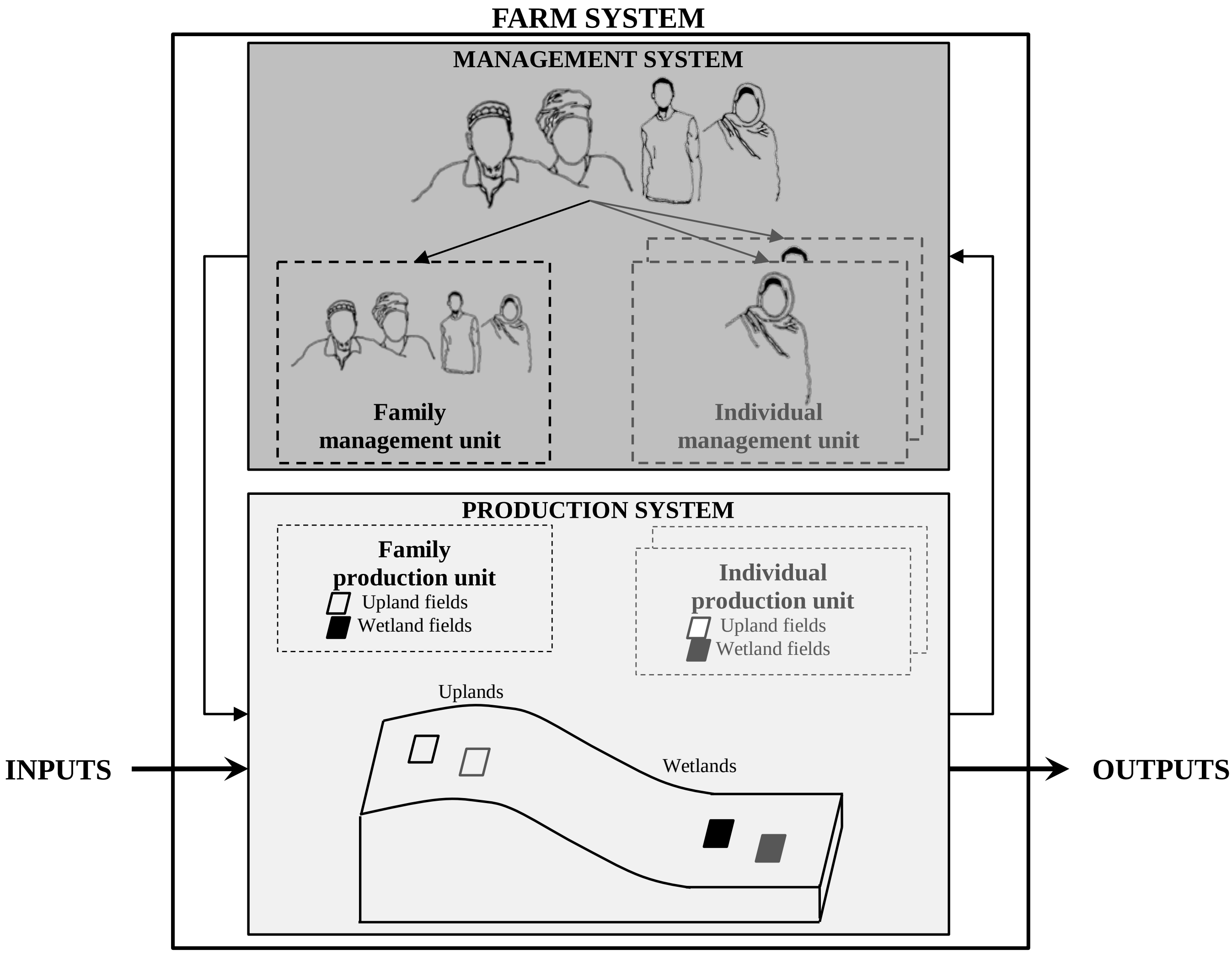


Figure 1: Model of the farm system

(adapted from Dogliotti, 2011; McCown, 2001; Sorensen & Kristensen, 1992)

Different patterns of family fields and individual fields result from different ways of dividing productive resources (e.g., land, family labour, cash for purchasing chemical inputs and hiring labour) and profit (in the form of food or cash) within farms. This division may be shaped by cooperation and conflict among family farm members (Caretta and Börjeson, 2014; Doss, 2013; Himmelweit et al., 2013). In this study we address resource division between family fields and individual fields as one of the factors defining farm resource-use strategies (all-for-one versus each-for-himself resource-use strategies). Understanding the diversity in strategies is expected to help generating and identifying meaningful field and farm level options to increase food crop production and improve farmer livelihoods (Cortez-Arriola et al., 2015; Tittonell et al., 2010). Targeting of such interventions has thus far not considered resource division between family fields and individual fields. Little is known about the ways in which resources are divided between family fields and individual fields. Much less is known about how this resource division affects the spatio-temporal aspects of the farm production system, in particular the uptake of cropping in wetlands as compared to uplands. In relation to unlocking the potential of wetlands, this lack of knowledge hampers meaningful proposals on alternative farm systems as changing the existing division of resources may conflict with socially embedded allocation patterns.

Our objective was to investigate the different ways in which resources are divided between family fields and individual fields and the resulting uptake of cropping in wetlands for different farm types, as the first step towards suggestions for enhancing rice production and market gardening in wetlands. We studied farms in two case-study villages in Benin with contrasting agro-ecological and socio-economic conditions: Zonmon in the southern part and Pelebina in the north-western part. To our knowledge, this is the first report that uses farm typologies to establish the relation between management systems and resulting production systems.

2. Materials and methods

2.1. Case-study villages

Case-study village choice was subsequent to a rapid regional assessment of the various wetland agro-ecosystems from south to north in Benin. Preliminary zoning was carried out by combining available data sources: a digital map of a number of wetlands in the upper Oueme catchment in north-western Benin (IMPETUS project[1]); a digital map of a number of wetlands in the Mono-Couffo region in south-western Benin (RAP project[2]); and digital maps of the hydrographic network, roads, villages and major urban markets (IMPETUS project[1], SMART-IV project[3]). To ensure that rice and market garden crops were found in wetlands and to collect additional information on village conditions, pre-identified villages were surveyed. This resulted in selecting two case-study villages that were close to an urban market and situated in markedly different agro-ecological and socio-economic conditions (Table 1 and Figure 2).

[1] http://www.impetus.uni-koeln.de/en/project.html
[2] http://ongoing-research.cgiar.org/factsheets/realizing-the-agricultural-potential-of-inland-valley-lowlands-in-sub-saharan-africa-while-maintaining-their-environmental-services-rap-project/
[3] https://smartiv.wordpress.com/about/

Table 1: Main characteristics of the selected villages. Combination of crops in the same field is symbolized by plus signs.

	Zonmon	**Pelebina**
Location	Southern Benin	North-western Benin
Agro-ecological zone	Zone des terres de barre	Zone Ouest Atacora
Rainfall distribution	Bimodal (long and short rainy season)	Unimodal (one rainy season)
Annual rainfall (1961-1990; mm)	1100 - 1200	> 1300
Dominant soil type (FAO)	Acrisol	Luvisol
Major soil types from upstream to downstream in uplands (farmer classification)	*Veyssa* (sandy soil), *kozo holo* (loamy soil)	*Wawate* (red lateritic soil), *turr* (yellow lateritic soil), *burum* (sandy soil)
Major soil types from upstream to downstream in wetlands (farmer classification)	*Veyssa* (sandy soil), *kozo holo* (loamy soil), *kozo dide* (heavy clay soil)	*Burum* (sandy soil), *vete* (sandy-clay soil), *sewer* (loamy soil)
Elevation range (m)	10-85	385-450
Wetland type	One lowland with mixed flood regime (rainwater runoff and floodwater of the Oueme river) and three permanent streams	21 lowlands, including seven lowlands in which water is available during the dry season
Water management infrastructure	Damaged irrigation scheme	None
Population at village level (2013)	828	5964
Commune	Zangnanado	Djougou
Population density at commune level (inhabitants/km²; 2013)	104	68
Main ethnic groups	Mahi, transhumant Fula	Yom, sedentary Fula
Cropping systems	Fallow systems, continuous systems	Slash-and-burn systems, fallow systems, continuous systems
Major food crops	Maize (*Zea mays*)	*Noudosse* yam (early variety; *Dioscorea rotundata/cayenensis complex*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), *assina* yam (late variety; *Dioscorea rotundata/cayenensis complex*)
Major cash crops	Groundnut (*Arachis hypogaea*), rice (*Oryza sativa*)	Cotton (*Gossypium spp.*), soya (*Glycine max*), groundnut (*Arachis hypogaea*)
Major dry-season market garden crops	Sweet maize+celosia (*Zea mays+Celosia argentea*), groundnut+sweet maize (*Arachis hypogaea+Zea mays*), sweet potato (*Lopmoea batatas*), okra+celosia (*Abelmoschus esculentus+Celosia argentea*)	Okra (*Abelmoschus esculentus*)
Major groves	Oil palm trees (*Elaeis guineensis*)	Cashew trees (*Anacardium occidentale*)
Livestock system	Transhumant cattle (Fula) and small livestock; free grazing	Sedentary and transhumant cattle (Fula), small livestock; free grazing
Inputs for which credit is available	Seeds, fertilizers and cash to hire labour for rice cultivation	Seeds, fertilizers, herbicides and pesticides for cotton cultivation
Closest major urban market	Bohicon	Djougou
Distance to urban market (km)	36	38
Population of urban market (2013)	171,781	267,812
Distance to tar road (km)	3	0

Sources: (INSAE du Bénin, 2016; Judex and Thamm, 2008; MEPN, 2008; Youssouf and Lawani, 2002)

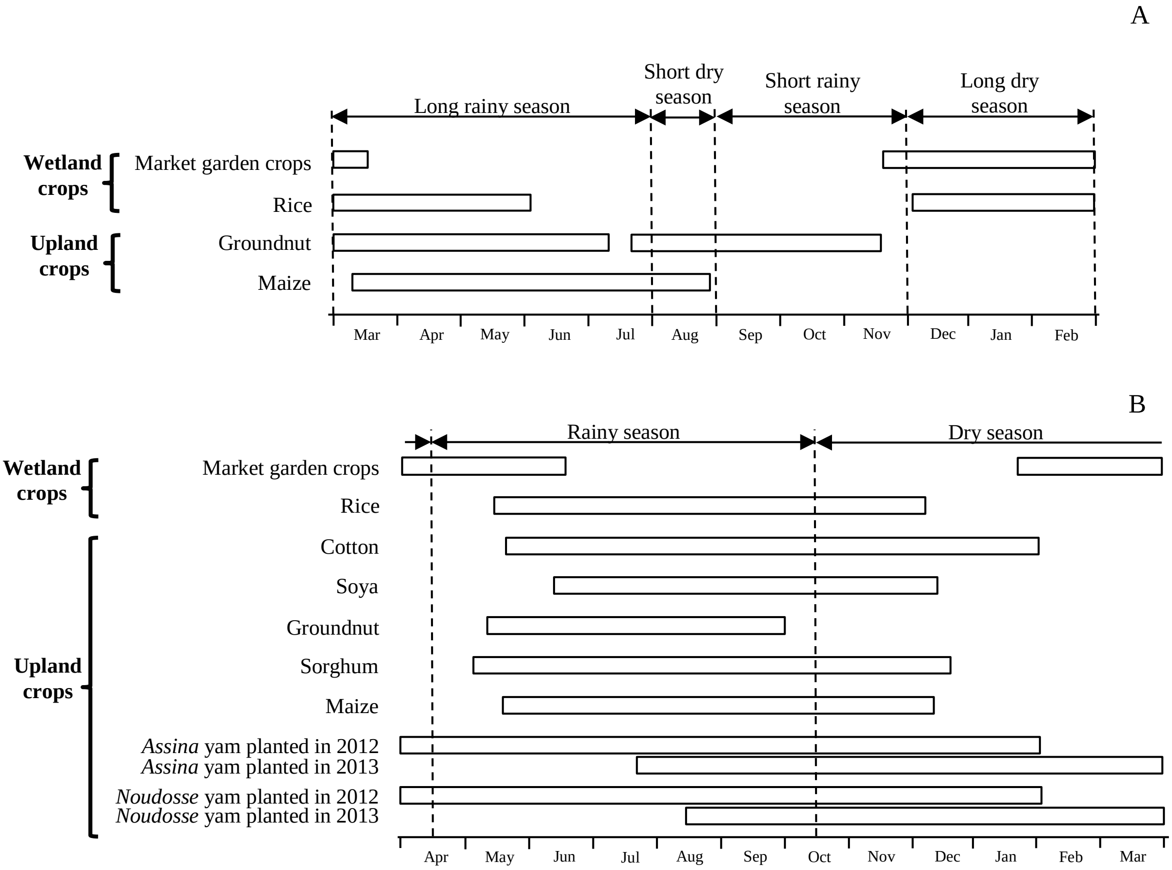


Figure 2: Agricultural calendars for major wetland and upland crops in (A) Zonmon, (B) Pelebina covering a year's cropping seasons. Note the rainy season starts earlier in Zonmon.

2.2 Farm survey

Social maps (Rim and Rouse, 2002) were drawn for each village with the help of village authorities to visualize where farm heads were living and to determine the total number of farms in each village. A random sample of 51 out of 134 (38%) farms from Zonmon and 50 out of 146 (34%) farms from Pelebina were surveyed.

In each sampled farm, semi-structured interviews with the farm head were used to gather information on the family structure and labour availability as well as to identify the management units and to locate sets of fields associated to each management unit. Family workers handling individual fields were interviewed to cross-validate farm head's information. A total of 102 family workers (51 farm heads and 51 individual family workers) in Zonmon and 143 family workers (50 farm heads and 93 individual family workers) in Pelebina were interviewed. To cover a year's cropping seasons, each family worker (the farm head or the individual family worker) was interviewed on three occasions in Zonmon: once during the 2012 long rainy season, once during the 2012 short rainy season and once during the 2013 long dry season, and on two occasions in Pelebina: once during the 2012 rainy season and once during the 2013 dry season (Figure 2).

Fields of each farm were mapped with GPS. Information collected on a field-by-field basis included land use; production orientation, i.e., food crop production or cash crop production (a field was considered under food crops when more than a half of its harvest was intended for self-consumption); cash spent on chemical inputs, i.e., herbicides, insecticides and fertilizers in the local currency (FCFA; 655.957 FCFA = 1 €); cash spent on hiring workforce (FCFA); land ownership; and major landscape unit, i.e., upland or wetland. Fields were classified as belonging to wetlands when their manager assessed that they were suitable for wetland rice or dry-season market garden crops.

Farm types were ranked based on resource endowment described by land and labour assets; material assets; livestock assets; and cash available for purchasing chemical inputs and hiring labour. Amounts of cash credits provided by extension services for rice and cotton cultivation in Zonmon, and in Pelebina, respectively were not taken into account to bring out a farm's own cash endowment. Type x farms were classified as better endowed than Type y farms when (i) at least one indicator was larger for Type x farms than for Type y farms and (ii) the other indicators were similar for both farm types.

Food self-sufficiency was assessed by asking the farm head for the number of months during which farm members could satisfy their food needs from their own production over the study year.

2.3 Farm typologies and detailed characterisation

A farm typology was developed for each village. Types were identified by combining Principal Component Analysis (PCA) and hierarchical clustering. Data were normalised and standardised. First, 43 candidate variables in Zonmon and 48 candidate variables in

Pelebina were defined (Table 2). Variables were related to levels of resource endowment and resource-use strategies. A first PCA was performed to select a subset of variables based on their quality of representation in a two-dimensional space and to reduce dimensionality; variables for which the sum of the squared loadings on the two first principal components was larger than 0.5 were included in a second PCA. Farm scores on PC1 and PC2 were finally used in a Ward's minimum variance cluster analysis. The choice of the number of types was driven by a jump in dissimilarity and our interpretability of types.

Supplementary variables were used for detailed characterisation of each farm type. These supplementary variables consisted of variables included in the first PCA but discarded in the second PCA as well as combinations of variables such as the ratio of the area farmed in wetlands to the total area farmed. Given the skewness of the data, the non-parametric Kruskal-Wallis test was used to test for differences among farm types. When significant differences were found, Dunn tests were performed using Bonferroni as p-value adjustment method and a significance probability limit of 0.05. Outlier farms were included in the PCA and the Ward's minimum variance clustering as they account for farm diversity in villages but they were disregarded when testing for differences among farm types.

Table 2: Candidate variables to be included in the PCA

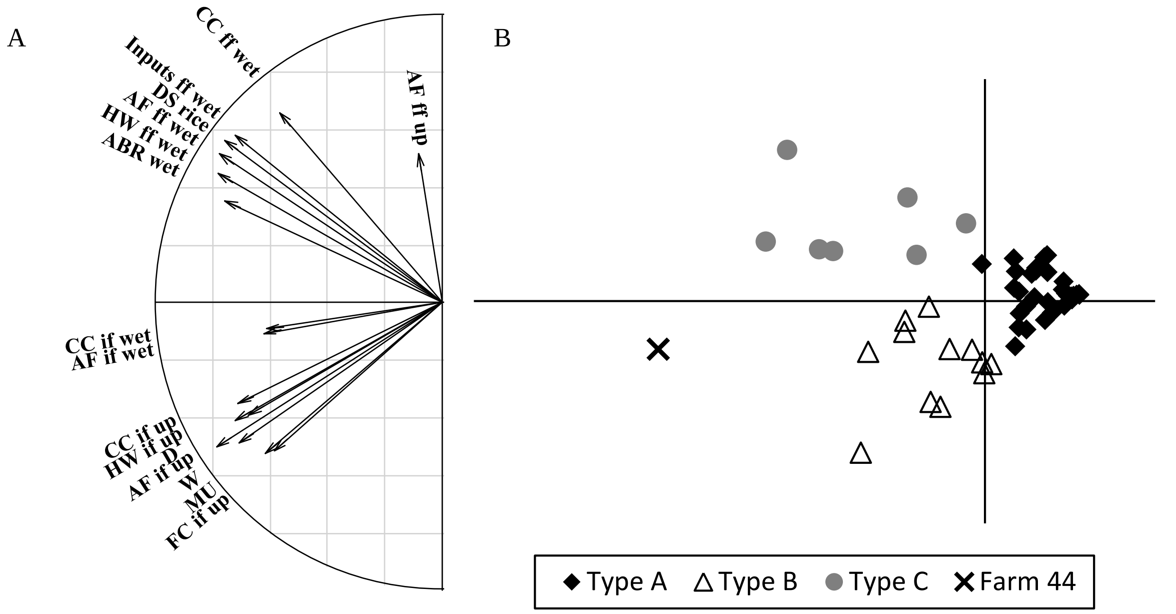
Zonmon (43 variables)	**Pelebina** (48 variables)
Age of the farm head	Age of the farm head
Family members supported by the farm	Family members supported by the farm
Family members working in the farm	Family members working in the farm
Management units	Management units
Area owned in uplands (ha)	Area owned in uplands (ha)
Area owned in wetlands (ha)	Area owned in wetlands (ha)
Area borrowed in uplands (ha)	Area borrowed in uplands (ha)
Area borrowed or rented in wetlands (ha)	Area borrowed in wetlands (ha)
Livestock (TLU)	Livestock (TLU)
Family fields in uplands (ha)	Family fields in uplands (ha)
Individual fields in uplands (ha)	Individual fields in uplands (ha)
Family fields in wetlands (ha)	Family fields in wetlands (ha)
Individual fields in wetlands (ha)	Individual fields in wetlands (ha)
Food crops in family fields in uplands (ha)	Food crops in family fields in uplands (ha)
Food crops in individual fields in uplands (ha)	Food crops in individual fields in uplands (ha)
Food crops in family fields in wetlands (ha)	Food crops in family fields in wetlands (ha)
Food crops in individual fields in wetlands (ha)	Food crops in individual fields in wetlands (ha)
Cash crops in family fields in uplands (ha)	Cash crops in family fields in uplands (ha)
Cash crops in individual fields in uplands (ha)	Cash crops in individual fields in uplands (ha)
Cash crops in family fields in wetlands (ha)	Cash crops in family fields in wetlands (ha)
Cash crops in individual fields in wetlands (ha)	Cash crops in individual fields in wetlands (ha)
Maize (ha)	Noudosse yam planted in 2012 (ha)
Rainy-season rice (ha)	Noudosse yam planted in 2013 (ha)
Dry-season rice (ha)	Assina yam planted in 2012 (ha)
Cassava (ha)	Assina yam planted in 2013 (ha)
Sweet potato (ha)	Cassava transplanted in 2011 (ha)
Groundnut (ha)	Cassava transplanted in 2012 (ha)
Cowpea (ha)	Maize (ha)
Bambara nut (ha)	Sorghum (ha)
Geocarpa groundnut (ha)	Millet (ha)
Soya (ha)	Rice (ha)
Rainy-season market garden crops (ha)	Groundnut (ha)
Dry-season market garden crops (ha)	Cowpea (ha)
Oil palm trees (ha)	Bambara nut (ha)
Fallow (ha)	Soya (ha)
	Cotton (ha)
	Rainy-season market garden crops (ha)
	Dry-season market garden crops (ha)
	Groves (ha)
	Fallow (ha)
Chemical inputs in family fields in uplands (FCFA)	Chemical inputs in family fields in uplands (FCFA)
Chemical inputs in individual fields in uplands (FCFA)	Chemical inputs in individual fields in uplands (FCFA)
Chemical inputs in family fields in wetlands (FCFA)	Chemical inputs in family fields in wetlands (FCFA)
Chemical inputs in individual fields in wetlands	Chemical inputs in individual fields in wetlands
Hired workforce in family fields in uplands (FCFA)	Hired workforce in family fields in uplands (FCFA)
Hired workforce in individual fields in uplands (FCFA)	Hired workforce in individual fields in uplands (FCFA)
Hired workforce in family fields in wetlands (FCFA)	Hired workforce in family fields in wetlands (FCFA)
Hired workforce in individual fields in wetlands (FCFA)	Hired workforce in individual fields in wetlands (FCFA)

3. Results

3.1. Farm typologies

3.1.1. Farm typology in Zonmon

A subset of 16 key variables was selected from the first PCA and included in the second PCA. Patterns revealed by the second PCA were interpreted in a two-dimensional space as PC1 and PC2 together explained 67% of original variance (Figure 3A). Farms were grouped into three types (the fourth type was disregarded as it only included farm 44; Figure 3B). Results of Kruskal Wallis tests indicated that the three farm types differed significantly with regard to the key variables, except for the area farmed in family fields in uplands (Table 3).



AF ff up: family fields in uplands (ha); **CC ff wet**: cash crops in family fields in wetlands (ha); **Inputs ff wet**: chemical inputs in family fields in wetlands (FCFA); **DS rice**: dry-season rice (ha); **AF ff wet**: Family fields in wetlands (ha); **HW ff wet**: hired workforce in family fields in wetlands (FCFA); **ABR wet**: area borrowed or rented in wetlands (ha); **CC if wet**: cash crops in individual fields in wetlands (ha); **AF if wet**: individual fields in wetlands (ha); **CC if up**: cash crops in individual fields in uplands (ha); **HW if up**: hired workforce in individual fields in uplands (FCFA); **D**: family members supported by the farm; **AF if up**: individual fields in uplands (ha); **W**: family members working in the farm; **MU**: management units; **FC if up**: food crops in individual fields in uplands (ha)

Figure 3: Results of PCA and hierarchical clustering for Zonmon. (A) Correlation circle. Projection of the 16 variables in a two-dimensional space. Variables are symbolized by arrows. (B) Individuals factor map. Projection of farms in a two-dimensional space and farm types.

Table 3: Characteristics of farm types in Zonmon, based on the subset of the 16 variables included in the final PCA (in bold type) and on the supplementary variables (variables included in the first PCA but discarded in the second PCA and combinations of variables). Values represent medians. Different letters indicate differences in a characteristic among farm types at the 5% level.

	Type A		Type B		Type C	
Number of households	31		12		7	
Household distribution (%)	61		24		14	
Family members supported by the farm	5.0	a	7.5	b	8.0	b
Family members working in the farm	2.0	a	4.5	b	3.0	b
Management units	1.0	a	3.0	b	2.0	ab
Area borrowed or rented in wetlands (ha)	0.00	a	0.02	a	0.42	b
Area farmed in individual fields (total of upland and wetland fields; ha)	0.00	a	1.04	b	0.70	b
Area farmed in individual fields:total area farmed ratio	0.00	a	0.62	b	0.24	ab
Area farmed in wetlands (total of family and individual fields; ha)	0.12	a	0.28	a	1.09	b
Area farmed in wetlands:total area farmed ratio	0.14	a	0.21	ab	0.53	b
Family fields in uplands (ha)	0.71		0.43		1.04	
Individual fields in uplands (ha)	0.00	a	0.95	b	0.50	ab
Family fields in wetlands (ha)	0.05	a	0.00	a	1.00	b
Individual fields in wetlands (ha)	0.00	a	0.15	b	0.04	ab
Food crops in family fields in uplands (ha)	0.43		0.36		0.22	
Food crops in individual fields in uplands (ha)	0.00	a	0.41	b	0.05	ab
Food crops in family fields in wetlands (ha)	0.00		0.00		0.02	
Food crops in individual fields in wetlands (ha)	0.00		0.00		0.00	
Cash crops in family fields in uplands (ha)	0.29		0.00		0.23	
Cash crops in individual fields in uplands (ha)	0.00	a	0.23	b	0.15	b
Cash crops in family fields in wetlands (ha)	0.05	a	0.00	a	0.94	b
Cash crops in individual fields in wetlands (ha)	0.00	a	0.14	b	0.04	b
Dry-season market garden crops (ha)	0.03	a	0.12	b	0.05	ab
Dry-season rice (ha)	0.00	a	0.00	a	0.83	b
Oil palm trees (ha)	0.53		1.14		2.10	
Chemical inputs in family fields in uplands (FCFA)	0		0		1500	
Chemical inputs in individual fields in uplands (FCFA)	0	a	0	ab	0	b
Chemical inputs in family fields in wetlands (FCFA)	0	a	150	a	41,522	b
Chemical inputs in individual fields in wetlands (FCFA)	0	a	0	b	0	ab
Hired workforce in family fields in uplands (FCFA)	36,600		16,800		51,700	
Hired workforce in individual fields in uplands (FCFA)	0	a	50,900	b	45,400	ab
Hired workforce in family fields in wetlands (FCFA)	0	a	0	a	245,167	b
Hired workforce in individual fields in wetlands (FCFA)	0	a	5400	b	2000	ab

In Zonmon, farms corresponded mostly to nuclear households, i.e., a husband (the farm head), his wife or wives, and his children. In 20% of farms (10 out of 50 farms), the parents of the husband or collateral relatives added to the nuclear household. In the 50 farms, 49 individual workers (corresponding to 49 individual management units) were given at least one field to manage. Individual workers were mostly the farm head's wife or wives (Table 4).

Table 4: Composition of management systems for 50 farms in Zonmon and 47 farms in Pelebina. Values represent counts. Proportions are indicated between brackets.

	Zonmon	Pelebina
Family management unit	50	47
Male-headed farms	43 (86%)	47 (100%)
Female-headed farms	7 (14%)	0 (0%)
Individual management unit	49	76
Wife	39 (80%)	30 (39%)
Mother	5 (10%)	7 (9%)
Son	5 (10%)	34 (45%)
Brother	0 (0%)	5 (7%)

Type A farms were the least endowed farms (Table 5). They were self-sufficient for 8-9 months year^{-1} like Type B and Type C farms. They corresponded mostly to monogamous households or to the female-headed households (Table 4), which were widow-headed households. They were small households with few family members both supported by the farm and working in the farm (Table 3). In most of these farms, family workers worked together in all fields under the farm head's supervision, i.e., there was only the family management unit in the farm. The farm head focused his or her agricultural activities on uplands. The ratio of the area farmed in wetlands to the total area farmed was 0.14. These farms used few chemical inputs irrespective of upland or wetland. Their expenditure on hired workforce in family fields in uplands was similar to other farm types.

Table 5: Resource endowment and food self-sufficiency indicators for farm types in Zonmon. Values represent medians. Different letters indicate differences in an indicator among farm types at the 5% level. Resource endowment increases from Type A to Type C.

	Type A		Type B		Type C	
Number of households	31		12		7	
Household distribution (%)	61		24		14	
Area owned in uplands (ha)	0.80	a	2.12	b	3.64	b
Area owned in wetlands (ha)	0.13	a	0.28	ab	0.68	b
Family members working in the farm	2.0	a	4.5	b	3.0	b
Bikes	0.0	a	1.0	ab	1.0	b
Motorbikes	0.0		0.5		1.0	
Knapsack sprayers	0.0		0.0		0.0	
Pirogues	0.0		0.0		1.0	
Livestock (TLU)	0.16		0.39		0.41	
Chemical inputs (FCFA)*	0		870		9315	
Hired workforce (FCFA)*	39,400	a	110,950	ab	194,802	b
Months of food self-sufficiency	8.0		8.5		9.0	

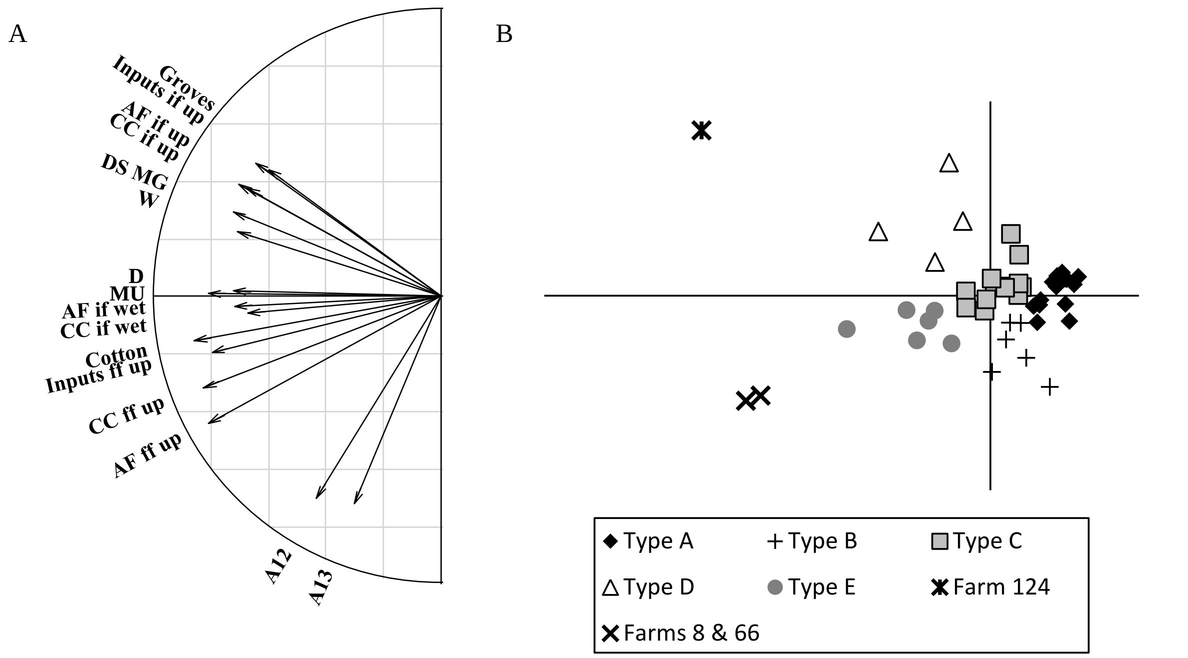
* Amounts of cash credits provided by extension services for rice cultivation were not included

Type B farms were moderately endowed farms (Table 5). They were polygamous households: the median number of wives in Type B farms exceeded those in Type A and Type C farms, i.e., 2 wives compared to 1 ($p < 0.05$). A large number of family members were both supported by the farm and working in the farm (Table 3). Farm activities were focused on uplands like in Type A farms. In Type B farms however, at least one individual management unit was found and in 11 out of 12 Type B farms two to three individual management units were found. Food crops were produced in uplands both by the farm head and by individual female workers. Cash crops were produced in uplands and wetlands by individual female workers only. Major cash crops included groundnut in uplands and market garden crops in wetlands. Individual female workers spent large amounts of money on hiring workforce compared to other farm types, both in uplands and wetlands. Finally, individual female workers contributed substantially to agricultural production and the ratio of the area farmed in individual fields to the total area farmed was larger than in other farm types.

Type C farms were the best endowed farms (Table 5). They were large households with family members both supported by the farm and working in the farm, similar to Type B farms (Table 3). Farm activities were spread between uplands and wetlands. The area farmed in wetlands accounted for slightly more than half of the total area farmed. The farm head managed large rice fields in wetlands with high levels of chemical input and external labour. In 6 out of 7 Type C farms, 1 to 2 individual management units were found. Unlike Type B farms, however, food crops were produced in uplands mostly by the farm head and cash crops were produced in uplands and wetlands both by the farm head and by individual female workers. The areas farmed by individual female workers in uplands and in wetlands were intermediate between Type A and Type B farms. As Type C farms also had family fields in wetlands, the ratio of the area farmed in individual fields to the total area farmed was smaller than in Type B farms.

3.1.2. Farm typology in Pelebina

A subset of 16 key variables was selected from the first PCA and included in the second PCA. Patterns revealed by the second PCA were interpreted in a two-dimensional space as PC1 and PC2 together explained 63% of original variance (Figure 4A). Farms were grouped into five types (the sixth and the seventh type were disregarded as they only included farm 124 and farms 8 and 6, respectively; Figure 4B). Results of Kruskal Wallis tests indicated that the five farm types differed significantly with regard to the key variables (Table 6).



Groves: groves (ha); **Inputs if up**: chemical inputs in individual fields in uplands (FCFA); **AF if up**: individual fields in uplands (ha); **CC if up**: cash crops in individual fields in uplands (ha); **DS MG**: dry-season market gardening (ha); **W**: family members working in the farm; **D**: family members supported by the farm; **MU**: management units; **AF if wet**: individual fields in wetlands (ha); **CC if wet**: cash crops in individual fields in wetlands (ha); **Cotton**: cotton (ha); **Inputs ff up**: chemical inputs in family fields in uplands (FCFA); **CC ff up**: cash crops in family fields in uplands (ha); **AF ff up**: family fields in uplands (ha); **A12**: *assina* yam planted in 2012 (ha); **A13**: *assina* yam planted in 2013 (ha)

Figure 4: Results of PCA and hierarchical clustering for Pelebina. (A) Correlation circle. Projection of the 16 variables in a two-dimensional space. Variables are symbolized by arrows. (B) Individuals factor map. Projection of farms in a two-dimensional space and farm types.

Table 6: Characteristics of farm types in Pelebina, based on the subset of the 16 variables included in the final PCA (in bold type) and on the supplementary variables (variables included in the first PCA but discarded in the second PCA and combinations of variables). Values represent medians. Different letters indicate differences in a characteristic among farm types at the 5% level.

	Type A		Type B		Type C		Type D		Type E	
Number of households	17		6		14		4		6	
Household distribution (%)	34		12		28		8		12	
Family members supported by the farm	7.0	a	9.0	ab	10.0	ab	12.5	ab	17.5	b
Family members working in the farm	3.0	a	3.0	ab	6.0	b	8.5	b	7.5	b
Management units	1.0	a	2.0	ab	4.0	b	3.5	ab	3.5	b
Area farmed in individual fields (total of upland and wetland fields; ha)	0.01	a	0.21	ab	0.57	b	1.14	b	0.26	ab
Area farmed in individual fields:total area farmed ratio	0.00	a	0.05	ab	0.19	b	0.15	b	0.03	ab
Area farmed in wetlands (total of family and individual fields; ha)	0.03		0.04		0.29		0.57		0.54	
Area farmed in wetlands:total area farmed ratio	0.02		0.01		0.08		0.10		0.09	
Family fields in uplands (ha)	1.62	a	4.38	bc	2.82	ab	4.29	abc	5.48	c
Individual fields in uplands (ha)	0.01	a	0.19	ab	0.54	b	1.04	b	0.23	ab
Family fields in wetlands (ha)	0.03		0.02		0.19		0.47		0.48	
Individual fields in wetlands (ha)	0.00	a	0.00	ab	0.03	bc	0.10	c	0.05	abc
Food crops in family fields in uplands (ha)	1.37	a	3.36	b	1.88	a	2.70	ab	2.70	ab
Food crops in individual fields in uplands (ha)	0.00		0.00		0.01		0.06		0.00	
Food crops in family fields in wetlands (ha)	0.00		0.02		0.14		0.17		0.29	
Food crops in individual fields in wetlands (ha)	0.00		0.00		0.00		0.00		0.00	
Cash crops in family fields in uplands (ha)	0.22	a	0.33	a	0.76	a	1.04	ab	3.40	b
Cash crops in individual fields in uplands (ha)	0.00	a	0.09	ab	0.38	b	0.99	b	0.13	ab
Cash crops in family fields in wetlands (ha)	0.00	a	0.00	ab	0.02	ab	0.15	ab	0.10	b
Cash crops in individual fields in wetlands (ha)	0.00	a	0.00	ab	0.03	bc	0.10	c	0.04	abc
Assina yam planted in 2012 (ha)	0.00	a	0.34	b	0.04	ab	0.00	a	0.24	ab
Assina yam planted in 2013 (ha)	0.00	a	0.35	b	0.03	ab	0.00	a	0.16	ab
Cotton (ha)	0.00	a	0.00	ab	0.76	ab	1.20	ab	3.17	b
Dry-season market garden crops (ha)	0.00	a	0.02	ab	0.05	ab	0.20	b	0.13	ab
Groves (ha)	0.10	a	0.12	ab	0.48	ab	5.31	b	3.03	ab
Chemical inputs in family fields in uplands (FCFA)	7080	a	5010	a	45,750	ab	55,475	ab	238,637	b
Chemical inputs in individual fields in uplands (FCFA)	0	a	0	a	0	a	22,500	b	0	a
Chemical inputs in family fields in wetlands (FCFA)	0		240		0		855		1680	
Chemical inputs in individual fields in wetlands (FCFA)	0		0		0		270		875	
Hired workforce in family fields in uplands (FCFA)	23,000		16,750		6250		18,750		80,375	
Hired workforce in individual fields in uplands (FCFA)	0		3000		3600		5250		3000	
Hired workforce in family fields in wetlands (FCFA)	0		0		0		3750		7850	
Hired workforce in individual fields in wetlands (FCFA)	0	a	0	ab	0	ab	3350	ab	3750	b

In Pelebina, farms corresponded either to nuclear households (57%, or 27 out of 47) or to extended families (43%, or 20 out of 47). In extended families, farms included a husband (the farm head), his wife or wives, his children and other collateral relatives (e.g., his parents, brothers, in-laws if brothers or sons were married, grandchildren, nephews or nieces). In the 47 farms, 76 individual family workers (corresponding to 76 individual management units) were given at least one field to manage. Individual workers were mostly sons or the farm head's wife or wives (Table 4).

Type A farms were the least endowed farms (Table 7). They achieved year-round food self-sufficiency like the other farm types. They were small households with relatively few family members both supported by the farm and working in the farm (Table 6). In most of these farms, family workers worked together in all fields under the farm head's supervision, i.e., there was only the family management unit in the farm. The farm head focused his agricultural activities on uplands. The ratio of the area farmed in wetlands to the total area farmed was 0.02 with no differences among farm types. These farms used few chemical inputs.

Table 7: Resource endowment and food self-sufficiency indicators for farm types in Pelebina. Values represent medians. Different letters indicate differences in an indicator among farm types at the 5% level. Resource endowment increases from Type A to Type E.

	Type A		Type B		Type C		Type D		Type E	
Number of households	17		6		14		4		6	
Household distribution (%)	34		12		28		8		12	
Area owned in uplands (ha)	4.58	a	6.88	ab	5.96	ab	10.53	ab	12.53	b
Area owned in wetlands (ha)	0.18		0.34		0.63		0.64		1.97	
Family members working in the farm	3.0	a	3.0	ab	6.0	b	8.5	b	7.5	b
Bikes	0.0		0.5		1.0		0.5		1.0	
Motorbikes	0.0		1.0		1.0		1.0		1.0	
Knapsack sprayers	0.0		0.0		0.5		1.5		1.0	
Livestock (TLU)	0.0		0.0		0.0		0.0		0.0	
Chemical inputs (FCFA)*	7080	a	8250	ab	29,602	abc	53,345	bc	107,163	c
Hired workforce (FCFA)	27,500		30,250		25,750		21,000		112,500	
Months of food self-sufficiency	12		12		12		12		12	

* Amounts of cash credits provided by extension services for cotton cultivation were not included

Type B farms were better endowed than Type A farms but less endowed than Type C, Type D, and Type E farms (Table 7). They were medium-size households with an intermediate number of family members both supported by the farm and working in the farm (Table 6). Like in Type A farms, farm activities were focused on uplands. Upland fields under food crops included *noudosse* yam fields (an early variety planted on large and high mounds) like in other farm types but also large *assina* yam fields (a late variety planted on small mounds) compared to other farm types. As a result, the area farmed in family fields in uplands was large and did not differ strongly from that of Type E farms (see below). The number of management units, the area farmed in individual fields as well as the ratio of the area farmed in individual fields to the total area farmed were intermediate compared to other farm types. Individual family workers who were granted fields mainly grew cash crops in uplands. These farms used few chemical inputs.

Type C farms were moderately endowed farms (Table 7) consisting of medium-size households (Table 6). The number of family members supported by the farm was similar to Type B farms. The number of family members working in the farm, however, was larger than in Type B farms and similar to Type D and Type E farms. Farm activities were focused on uplands. The number of management units was large and similar to Type E farms. The area farmed in individual fields as well as the ratio of the area farmed in individual fields to the total area farmed were large and similar to Type D farms. Individual family workers mostly grew cash crops in uplands, in particular soya. They also grew cash crops in wetlands, in particular dry-season market garden crops. Chemical inputs were allocated to family fields in uplands and used moderately compared to other farm types.

Type D farms were moderately endowed farms (Table 7). They were medium-size households similar to Type C farms, i.e., with an intermediate number of family members supported by the farm and a large number of family members working in the farm (Table 6). Farm activities were focused on uplands. The area of groves, which were owned and managed by the farm head, was larger than in other farm types. The number of management units was intermediate and similar to Type B farms. The area farmed in individual fields as well as the ratio of the area farmed in individual fields to the total area farmed, however, were large and similar to Type C farms. Individual family workers mostly grew cash crops in uplands, in particular cotton or soya. They also grew cash crops in wetlands, in particular dry-season market garden crops. Chemical inputs were used moderately in family fields in uplands compared to other farm types. Larger amounts however, were allocated to individual fields in uplands.

Type E farms were the best endowed farms (Table 7). They were large households with a large number of family members both supported by the farm and working in the farm (Table 6). Farm activities were focused on uplands. The areas under cash crops in family fields in uplands and wetlands were larger than in other farm types. Most farm heads managed large cotton fields in uplands and dry-season market garden crops fields in wetlands. Chemical inputs were allocated to family fields in uplands and, as a result of cotton production larger amounts were used than in other farm types. The number of management units was large and similar to Type C farms. The area farmed in individual fields as well as the ratio of the area farmed in individual fields to the total area farmed, however, were intermediate and similar to Type B farms. Individual family workers mainly grew cash crops in uplands.

3.2. Land availability and farm expansion to wetlands

Results for both villages indicate that land availability did not constrain farm expansion to wetlands. Large proportions of land areas owned by farmers in both uplands and wetlands were left unexploited and could be borrowed by other farmers for cropping. Based on our farm samples, we estimated that areas under fallows of 1 year or more accounted for around 50% of the area owned in uplands in both Zonmon and Pelebina, and for 15 and 64% of the area owned in wetlands in Zonmon and in Pelebina, respectively. Taking the number of crop cycles per year in Zonmon into account (i.e., up to 3 crop cycles depending on the location of the field in the toposequence), farmers left between 40 and 48% of wetland areas unexploited. Moreover, in Zonmon, at the start of the rainy season 2012, village authorities offered a part of wetland areas belonging to the village community to farmers willing to cultivate rice. Type C farms took up the offer: Type A and Type B farms did not extend their wetland use and ownership.

3.3. Cultivation of traditional upland crops in wetlands

In Zonmon, we found the traditional wetland crops, dry-season rice and market garden crops on 85% of the area farmed in wetlands. In Pelebina, however, we found traditional upland food crops on 65% of the area farmed in wetlands. In Pelebina, wetlands were used to extend the time period during which ‘upland’ food crops could be grown. This particular function was used equally by farm heads of all farm types: no difference was found in the area under food crops in family fields in wetlands among farm types. Major food crops grown in wetlands by farm heads included *noudosse* yam, maize and cassava (44%, 17% and 11% of the area farmed in family fields in wetlands, respectively). These crops were preferably cultivated in uplands (77% of *noudosse* fields, 87% of maize fields and 86% of cassava fields were located in uplands). To maximize the area under food crops and in case of delay in completing farming operations during the rainy season, these crops were also cultivated in wetlands, on the border to uplands so that flooding risks were limited. *Noudosse* yams were planted on large and high mounds and mounding with a hoe required moist soil. If mounding on upland soils was delayed to after the end of the rainy season, soils were too dry and therefore too hard for mounding. Wetland upper fringes then were used by farmers under labour and time pressure. Cassava was transplanted most of the time on *noudosse* yam mounds, just before yam harvest to avoid an additional mounding. Therefore, if *noudosse* yam was planted in wetlands, the following crop in the cropping sequence, i.e., cassava was transplanted in wetlands. If farmers were not able to sow maize in a timely manner in uplands, it was also sown in wetlands. In that way maize was provided with enough water during its cycle though at the risk of flooding before the harvest.

3.4. Labour allocation strategies and the uptake of rice and market garden crops in wetlands

We found larger rice and market garden crop areas in wetlands in better-endowed farm types comprising individual management units than in least-endowed farm types comprising only the family management unit. Among the well-endowed farm types, we found different strategies to divide resources between family fields and individual fields. In some well-endowed farm types, large family fields coexisted with small individual fields while in others, small family fields coexisted with large individual fields. Except in Type C farms in Zonmon, wetland areas were only cultivated with market garden crops during the dry season when the labour demand on upland fields was low (Figure 2).

In Zonmon, the largest areas in wetlands were found in Type C farms, which were the best endowed in labour (Table 8). In Type A farms, labour resources were all allocated to family fields. The small number of family workers and the small amount of hired labour were mainly allocated to upland fields with only small areas of dry-season market garden crops in wetlands. In Type B farms, labour resources were allocated to both family and individual fields. The large number of family workers and the intermediate amount of hired labour were mainly allocated to family and individual fields in uplands with only small areas of dry-season market garden crops in individual fields in wetlands.

Table 8: Summary of labour endowment, upland areas, and resulting areas under rice and market garden crops in wetlands for farm types in Zonmon. Values represent medians. Different letters indicate differences in an indicator among farm types at the 5% level.

		Type A		Type B		Type C	
Family members working in the farm		2.0	a	4.5	b	3.0	b
Hired workforce (FCFA)*		39,400	a	110,950	ab	194,802	b
Upland areas	Family fields in uplands (ha)	0.71		0.43		1.04	
	Individual fields in uplands (ha)	0.00	a	0.95	b	0.50	ab
Wetland areas	Market garden crops in family fields (ha)	0.00		0.00		0.00	
	Market garden crops in individual fields (ha)	0.00	a	0.11	b	0.04	ab
	Rice in family fields (ha)	0.00	a	0.00	a	0.85	b
	Rice in individual fields (ha)	0.00		0.00		0.00	

* Amounts of cash credits provided by extension services for rice cultivation were not included

A major strategy distinguishing Type C farms from Type A and Type B farms was the adoption of rice on family fields in wetlands. In Type C farms, farming operations on rice fields added to the labour demand for farming operations on maize and legumes family fields in uplands during the rainy season (Figure 2). The large number of family workers in the

Type C farms was not enough to cope with this labour demand and farm heads spent 1.5 times more cash on hiring labour per hectare of rice fields than the credit provided by the agricultural services for hiring labour (313,251 FCFA ha^{-1} and 206,000 FCFA ha^{-1}, respectively). Apparently farm heads were able to produce the extra required cash from their own resources. Priority given to family fields during the rainy season and fewer hired labour resources allocated to individual fields led to smaller individual fields in uplands compared to Type B farms but still allowed cultivating small areas with market garden crops in wetlands during the dry season. Finally, these small areas under market garden crops in individual fields added to the large areas under rice in family fields (Table 8).

In Pelebina, larger market garden crop areas in wetlands were found in Type C, Type D, and Type E farms, which were the best endowed in labour (Table 9). In Type A farms, labour resources were all allocated to family fields in uplands. In Type B farms, the intermediate number of family workers allowed expanding family fields and individual fields in uplands, and in particular, cultivating large *assina* yam family fields. Intermediate labour resources and priority given to *assina* yam family fields during both the rainy and the dry season (Figure 2) resulted in limited market garden crop areas in family and individual fields in wetlands.

Table 9: Summary of labour endowment, *assina* yam and cotton areas, and resulting areas under rice and market garden crops in wetlands for farm types in Pelebina. Values represent medians. Different letters indicate differences in an indicator among farm types at the 5% level.

		Type A		Type B		Type C		Type D		Type E	
Family members working in the farm		3.0	a	3.0	ab	6.0	b	8.5	b	7.5	b
Hired workforce (FCFA)		27,500		30,250		25,750		21,000		112,500	
Upland areas	Assina yam planted in 2012 (ha)	0.00	a	0.34	b	0.04	ab	0.00	a	0.24	ab
	Assina yam planted in 2013 (ha)	0.00	a	0.35	b	0.03	ab	0.00	a	0.16	ab
	Cotton (ha)	0.00	a	0.00	ab	0.76	ab	1.20	ab	3.17	b
Wetland areas	Market garden crops in family fields (ha)	0.00	a	0.00	a	0.00	ab	0.09	ab	0.07	b
	Market garden crops in individual fields (ha)	0.00	a	0.00	ab	0.03	b	0.10	c	0.04	bc
	Rice in family fields (ha)	0.00		0.00		0.00		0.00		0.00	
	Rice in individual fields (ha)	0.00		0.00		0.00		0.00		0.00	

In Type C and Type D farms, the large number of family workers allowed expanding family fields and individual fields in uplands. Labour division between family fields and individual fields resulted in limited market garden crop areas in family fields in wetlands and large market garden crop areas in individual fields in wetlands. The absence of *assina* yam family fields in Type D farms allowed cultivating larger market garden crop areas in individual fields in wetlands compared to Type C farms. Finally, in Type E farms, the large number of family workers allowed expanding family fields and individual fields in uplands, and in particular, cultivating large cotton and medium-size *assina* yam family fields. Labour division between family fields and individual fields resulted in relatively large market garden crop areas in family fields in wetlands and limited market garden crop areas in individual fields in wetlands.

4. Discussion

We investigated the different ways in which resources are divided between family fields and individual fields in uplands and wetlands among farm types to understand differences in the uptake of rice and market garden crops in wetlands. We found larger rice and market garden crop areas in wetlands in better-endowed farm types than in least-endowed farm types. Among the well-endowed farm types, we found different strategies to divide resources between family fields and individual fields. In most farm types, farm heads and individual family workers gave priority to upland areas and opted for cultivating market garden crops in wetlands during the dry season when labour demand for upland fields was low. In order to provide suggestions to enhance farm expansion to wetlands for rice production and market gardening, we discuss the different strategies to divide labour between family fields and individual fields on the one hand, and between upland and wetland areas on the other hand. We end by some considerations on the methods we used for understanding farm uptake of rice and market garden crops in wetlands.

4.1. Balancing labour between family fields and individual fields

We found several management units and greater numbers of family workers in the well-endowed farm types (Figure 5). Drawing on publications on family farms but also on cooperatives and feudal-like farms, Guirkinger et al. (2015) and Guirkinger & Platteau (2015, 2014) indicated that the awarding of individual fields within family farms is a strategy to avoid potential conflicts among family members and therefore to enhance commitment to family fields. These authors argued that contrary to individual production on individual fields, collective production on family fields is plagued by free-riding, which increases with the size of the workforce. They thus considered larger size of the workforce a key determinant of the existence of individual fields within farms. Individual fields allow workers to be rewarded in proportion to their labour (in terms of working hours and efficiency) contrary to family fields on which proportional rewards would be socially and operationally not likely (Guirkinger et al., 2015).

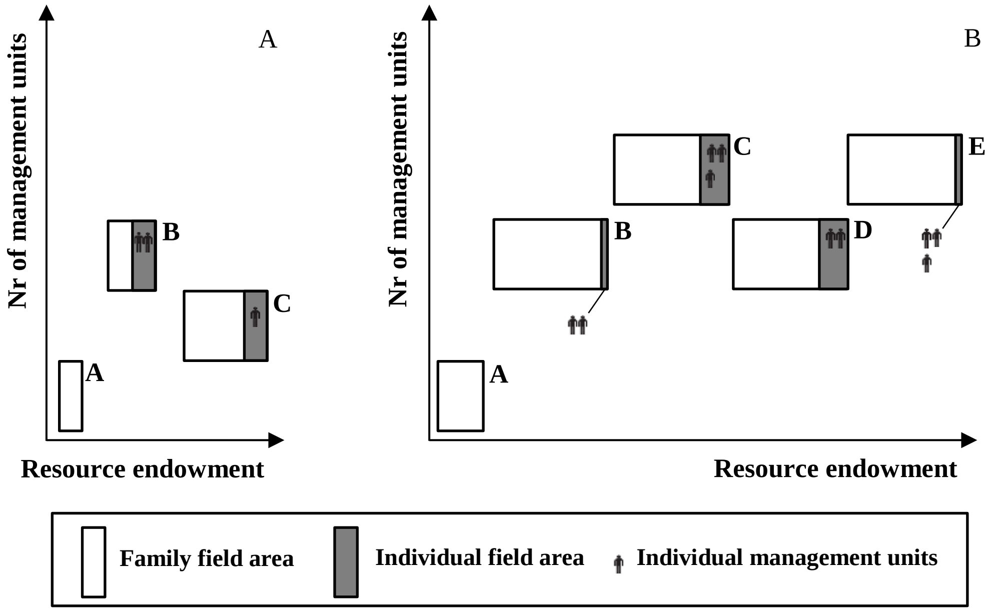


Figure 5: Schematic representation of differences in indicators of labour division between family fields and individual fields among farm types in Zonmon (A) and Pelebina (B). Differences in an indicator are symbolized by differences in the size of rectangles or in the number of individuals. Farm types are indicated by the letter at the upper right corner of rectangles.

In our context where land was not limiting, a larger number of family workers allowed increasing the total area farmed. At the same time, a larger number of family workers was associated with a larger number of management units. The increase in the total area farmed, however, was not shared equally between family fields and individual fields. We found different strategies to divide labour: in some farm types, large family fields coexisted with small individual fields while in the others, small family fields coexisted with large individual fields. These different labour division strategies between family fields and individual fields reflected different food and cash division strategies.

Large ratios of the area farmed in individual fields to the total area farmed were found in Type B farms in Zonmon and in Types C and Type D farms in Pelebina (Figure 5). Type B farms in Zonmon were polygamous households, unlike Type C farms. This more complex composition of the workforce may have increased the probability of conflicts compared to Type C farms. According to Guirkinger & Platteau (2014), in farms including several married couples, in-laws with more children may feel discriminated and in-laws with fewer children may feel exploited. We argue that the same reasoning holds for polygamous households. This is shown by Type B farms in Zonmon, where cash crops were produced by wives in individual fields only, and food crops were produced both by the farm head in family fields and by each of his wives in individual fields. In Type C and Type D farms in Pelebina, no such complex compositions of the workforce were found. In all farm types food crop production was ensured by the farm head in family fields, so that labour division strategies reflected cash division strategies. Larger ratios in the area farmed in individual fields to the total area farmed in Type C and Type D farms compared to Type B and Type E farms may be explained by (i) conflicting choices for cash crop or cash division between the farm head and individual workers (Foster and Rosenzweig, 2002); and/or (ii) differences in the balance between workers and non-workers. High proportions of workers in Type C and Type D farms may have allowed increasing individual profit relatively to family profit without being detrimental to the rest of the family needs for cash.

4.2. Labour allocation in upland areas versus labour allocation in wetland areas

Wetlands have been described as highly valuable for agricultural production (Giertz et al., 2012; Rodenburg et al., 2014; Schuyt, 2005; Wakatsuki and Masunaga, 2005; Windmeijer and Andriesse, 1993) and of growing interest for Sub-Saharan African farms (Saito et al., 2014; Sakané et al., 2011). In our case-study villages, median values of the ratio of the area farmed in wetlands to the total area farmed ranged from 14 and 21% for Types A and Type B farms to 53% for Type C farms in Zonmon and was 6% across the farm sample in Pelebina, with no difference among farm types (Tables 3 and 6). We suggest two reasons for the importance given to upland areas by farm heads and individual family workers: food self-sufficiency objectives and labour productivity.

Farm food self-sufficiency relied on maize and cassava in Zonmon, and on yam, maize and sorghum in Pelebina, all upland crops. Wetland rice and market garden crops were grown as cash crops to meet the local urban demand as suggested for West African countries (Bricas et al., 2016; Erenstein et al., 2006). Food self-sufficiency was independent of resource endowment in both villages: it existed for 8-9 months year^{-1} for all farm types in Zonmon and was achieved year-round for all farm types in Pelebina (Table 5 and 7). After achieving these levels of food self-sufficiency, remaining land, family labour and capital resources could be invested in cash crop areas, among which market garden crops and rice areas in wetlands. In Pelebina, wetlands were mainly used to grow traditional upland food crops. Thus, land use appeared strongly motivated by food self-sufficiency objectives, and led to prioritisation of upland over wetland areas.

A second reason to prioritise labour allocation in upland over wetland areas is the reward for labour. The biophysical characteristics of wetlands (availability of water, availability of soil moisture, soil fertility) imply large yields but also large labour requirements for soil preparation, intensive weeding, application of fertilizers, and water control (Balasubramanian et al., 2007; Guirkinger et al., 2015; Selim, 2012). In case-studies from

Nigeria, Sudan, Burkina Faso and Zimbabwe carried out 25 years ago (Scoones, 1991), land productivity was larger in wetlands than in uplands but labour productivity was higher in uplands. In the case-study context of labour scarcity rather than land scarcity, farmers may have tended to maximize labour productivity and hence gave priority to upland areas.

4.3. Suggestions to enhance farm expansion to wetlands for rice production and market gardening

In many studies, authors associate the expansion of agricultural production to wetlands in Sub-Saharan African family farms to growing land scarcity (Dixon and Wood, 2003; Jogo and Hassan, 2010; Kangalawe and Liwenga, 2005; Sakane et al., 2014; Turyahabwe et al., 2013) or growing fertile land scarcity (Giertz et al., 2012), following a Boserupian view. Our results indicate that a lack of upland areas is not a necessary condition for the expansion to wetlands. The proximity to urban markets may be a necessary condition (Erenstein et al., 2006), but not a sufficient condition for farms to expand rice and market garden crop areas. We showed that in our case-study context where land was not limiting both in uplands and in wetlands and urban markets were relatively close, farms expanded to wetlands provided they were better-endowed in labour, including family and hired labour. More specifically, the extent of rice and market garden crop areas was constrained by the amount of labour available after the requirements for family food crops had been met.

Increasing the amount of labour resources allocated to cash crops would require increasing the labour productivity of food crops. Increasing the labour productivity of food crops could be achieved (i) by focusing on yield-increasing alternatives that do not demand more labour, which would allow reducing the area under food crops and thus the total labour demand for food crop production; (ii) by focusing on labour-saving alternatives that do not decrease yield, which would allow reducing the total labour demand for food crop production while keeping the area under food crops constant; or (iii) by integrating both yield-increasing and labour-saving alternatives.

Increasing areas under rice and market garden crops in wetlands would require increasing current labour productivity to reach levels of at least that of upland cash crops, i.e., groundnut in Zonmon and cotton, soya, and groundnut in Pelebina. Feasible yield-increasing and labour-saving alternatives may be found among best local management practices, research knowledge on agronomic management, and/or affordable technologies (Ragasa et al., 2013; Rodenburg and Johnson, 2009, 2013; Tittonell and Giller, 2013).

Another approach would consist of improving farm labour endowment, which could be achieved by (i) developing off-farm opportunities allowing a positive balance between losses of family labour allocated to agricultural production and gains in cash for hiring labour (Babatunde and Qaim, 2010); (ii) developing or adjusting existing credits for hiring labour. In Zonmon, the implementation of credits for hiring labour on rice fields during our study appeared to be successful to increase rice areas at least for the best-endowed Type C farms. Rice areas have tripled since the period 2010-2012 to reach around 30 ha during the study period, allowing the best-endowed Type C farms to diversify their cash crops and cope with climatic uncertainty (Totin et al., 2015). Differences in labour endowment between Type B and Type C farms were related to differences in cash available for hiring labour on rice family fields. Therefore, increasing the amount of credit for hiring labour to cover the expenses of Type C farms on their rice family fields may allow wives in Type B farms to adopt rice in their individual fields. Assuming that all Type B farms would have cash available for hiring labour similar to Type C farms and would increase their rice areas to the average level of Type C farms, the additional rice area in the village would be 24 ha (+80%). Triggering rice adoption in Type A farms would require compensating for the difference in family labour endowment with Type B and Type C farms.

Development policies could draw on successful examples and integrate labour productivity-increasing and farm endowment-improving approaches. In Mali, credits for small-scale mechanisation and chemical inputs through cotton cultivation revolutionised agrarian and farm systems by improving both the labour productivity of maize, i.e., a major food crop, and that of cotton, i.e., the targeted cash crop (Dufumier and Bainville, 2006).

4.4. Methodological considerations

We adopted a systemic view of the farm, distinguishing both family and individual fields to understand differences in the uptake of cropping in wetlands among farm types. Considering family fields and individual fields as independent systems would have been misleading as family labour resources were shared between family and individual fields and food crops were usually produced in family fields.

Our method implied a prolonged period of residence in the rural communities. Resource allocation to family fields and individual fields may reflect underlying hierarchical conflicts (Foster and Rosenzweig, 2002; Guirkinger et al., 2015; Guirkinger and Platteau, 2014, 2015): it is a sensitive topic which requires trust from the farm members to obtain credible answers during interviews. Management units and the associated fields were identified by interviewing farm heads and all family workers that had individual fields. Interviews were held during each cropping season and combined with our own field observations, enabling triangulation of data. We question the feasibility of speeding up the gathering of such information through, e.g., a rapid rural appraisal or on-farm group discussions, which may limit the understanding of community and within-group complexities (Simpson et al., 2016; Townsley, 1996).

The purpose of our research was to gain in-depth understanding about the different ways in which resources are divided between family and individual fields and the resulting uptake of cropping in wetlands for different farm types. Our research was exploratory in that it focused on two case-study villages. Such case-study approach (Yin, 2014) was appropriate as there had been very little research on farm level constraints to cropping in wetlands in sub-Saharan Africa. In agreement with the case-study approach, the villages were selected to be contrasting in terms of agro-ecological and socio-economic conditions in search of consequences for wetland use. Results showed that farm labour abundance for cash crop production was a common factor driving the expansion to wetlands. This indicates that unless farm labour resource use is taken into account, agro-ecological and socio-economic conditions are not sufficient to explain the lack of uptake of rice and market garden crops in wetlands.

We identified options for developing rice production and market gardening in wetlands based on current farm resource endowment, food self-sufficiency objectives and on-farm resource allocation strategies. Our study focused on the farm system and depended on a single year snapshot. In, e.g., Type C farms in Zonmon, current agricultural activities to generate cash did not provide an explanation for the cash mobilized for hiring labour on rice fields: farm types did not differ in cash crop area in family fields in uplands, the area under oil palm trees (Table 3) or livestock assets at the time of the survey (Table 6). Cash generated from past agricultural activities and/or off-farm activities may have been redirected to rice cultivation. Moreover, during the study dry season, Type C farms used 19% less fertilizers on wetland fields than the amount of credit they received, which suggests fertilizers were diverted to upland fields the following year. Investigating resource flows over time and between on-farm and off-farm activities would be needed to reveal such allocation patterns, important for developing rice production and market gardening in wetlands.

5. Conclusion

The common farm typology approach was extended with an analysis of resource allocation to family fields and individual fields. The approach was based on the assumption that different patterns in resource division between family fields and individual fields may also affect resource division between uplands and wetlands, and thus the uptake of rice and market garden crops in wetlands.

We found no trade-off between the existence of individual fields and the area under rice and market garden crops in wetlands. We found, however, that labour abundance was the main factor driving both the occurrence of individual fields and the expansion of cropping in wetlands.

Family fields as well as individual fields for the polygamous Type B farms in Zonmon provided food shared by the family. When objectives of food self-sufficiency were achieved, remaining family and hired labour was allocated to cash crop production. The number of family workers was positively associated with the number of management units. Land was not a constraint in the case studies, and the choice of farm heads or individual family workers between upland crops and wetland crops was most likely driven by their comparative labour productivity. In wetlands, the choice between rice and market garden crops was apparently driven by the competition for labour needed for upland crops. Most farm types opted for cultivating market garden crops in wetlands during the dry season when labour demand for upland fields was low.

The results indicate that farm resource use is a critical and often missing factor to explain the lack of uptake of rice and market garden crops in wetlands. Labour shortages in our case studies kept farms from exploiting wetland resources for rice production and market gardening. Unlocking the potential of the wetlands can proceed by increasing labour productivity as well as by increasing labour availability. Increasing labour productivity in food crops and in rice and market garden crops would result in more wetland use. Options to do so include improving crop agronomy as well as reducing labour input by affordable technology. Options locally available at field level will be addressed in a next paper. Creating credit facilities would allow farmers to hire labour. Finally, options to increase wetland use for rice production and market gardening should target farm heads in conjunction with individual workers to be responsive to socially embedded resource allocation patterns.

Acknowledgement

We thank Seidou Ouorou Aliou and Gildas Edjrokinto for their contribution as translators in Pelebina and in Zonmon, respectively. We are grateful to the farmers who participated in our research. We thank village authorities and villagers for the warm welcome they have given us. We also thank the editor and two anonymous reviewers for their detailed comments and suggestions that helped us to improve the manuscript. This work was supported by the European Commission through the International Fund for Agricultural Development and the project “Realizing the agricultural potential of inland valley lowlands in sub-Saharan Africa while maintaining their environmental services Phase 2” [COFIN-ECG-65-WARDA]; and the Wageningen University INREF Fund.

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